CEASIOM
Improving the Tools for Aircraft Conceptual Design

Outline

- SimSAC project
- QCARD and its improvements
- Automatic CAD solid model generation
- Tests and assessments of design process

The Vision, Mission, Motivation & Consortium

- **Vision** A simulation tool for Stability & Control analysis in the conceptual design process with higher fidelity than current methods

- **Mission** Build and assess a simulation tool for S&C analysis in conceptual aircraft design with quantifiable uncertainty

- **Motivation** Standard aerodynamic data models in conceptual design provide too low-fidelity characteristics, which introduces mistakes in the Flight Control System. Correcting these mistakes later in design is very costly

Partner
KTH
Bristol University
Glasgow University
Aero Vodochody
Alenia
CFS Engineering
Dassault
EADS-M
Saab
CERFACS
DLR
FOI
ONERA
VZLU
TsAGI

See http://www.simsacdesign.org

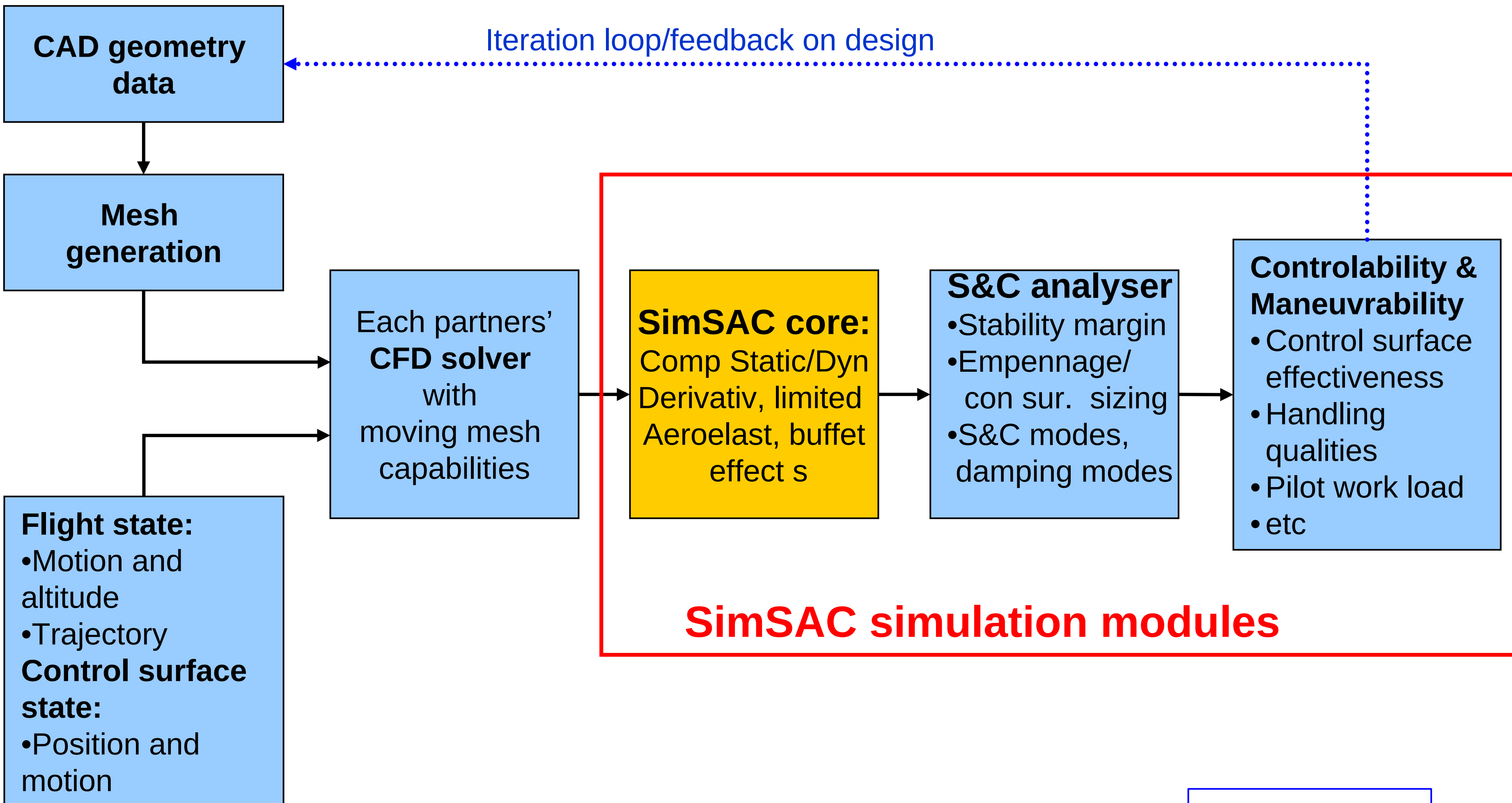
The Problem in Conceptual Design

The simplified methods used in the early phases of design do not give sufficient fidelity, which may result in mistakes which are costly to correct later in the design cycle.

Some examples pertaining to the Flight Control System are:

- **DC-9**: unexpected pitch-up and deep stall of T-tail lead to costly redesign
- **DC-9-50 & MD-80**: inadequate directional stiffness at high angles of attack in sideslip; adoption of low-set nose strakes
- **SAAB2000**: larger than expected wheel forces caused delay in certification; costly redesign of elevator control system
- **Boeing 777**: missed horizontal tail effectiveness led to larger than needed horizontal tail

SimSAC simulation modules in broad terms



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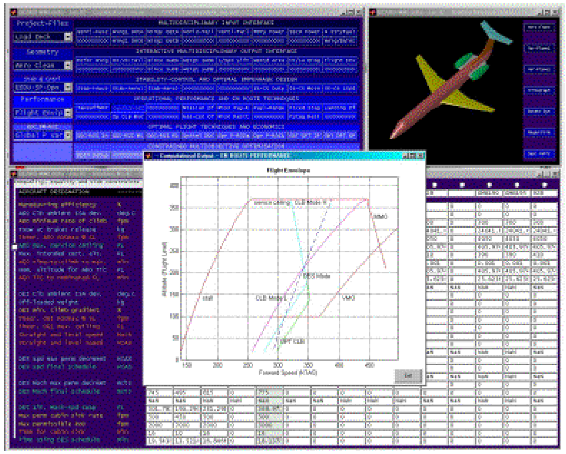
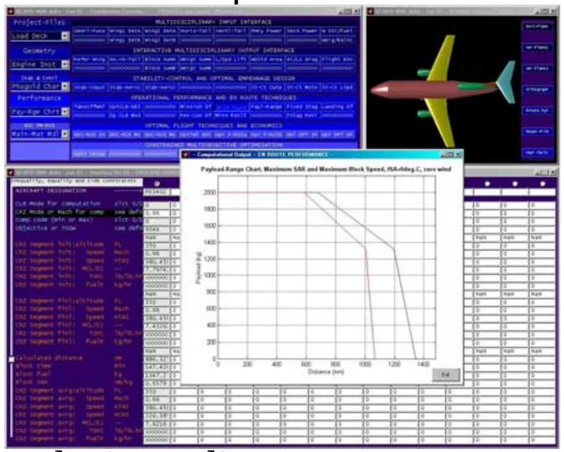
Simulation Environment: CEASIOM

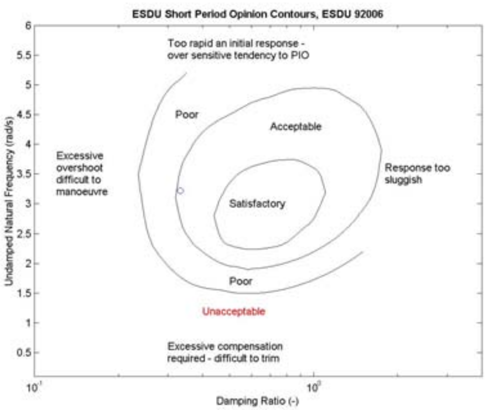
Computerised Environment for Aircraft Synthesis and Integrated Optimisation Methods



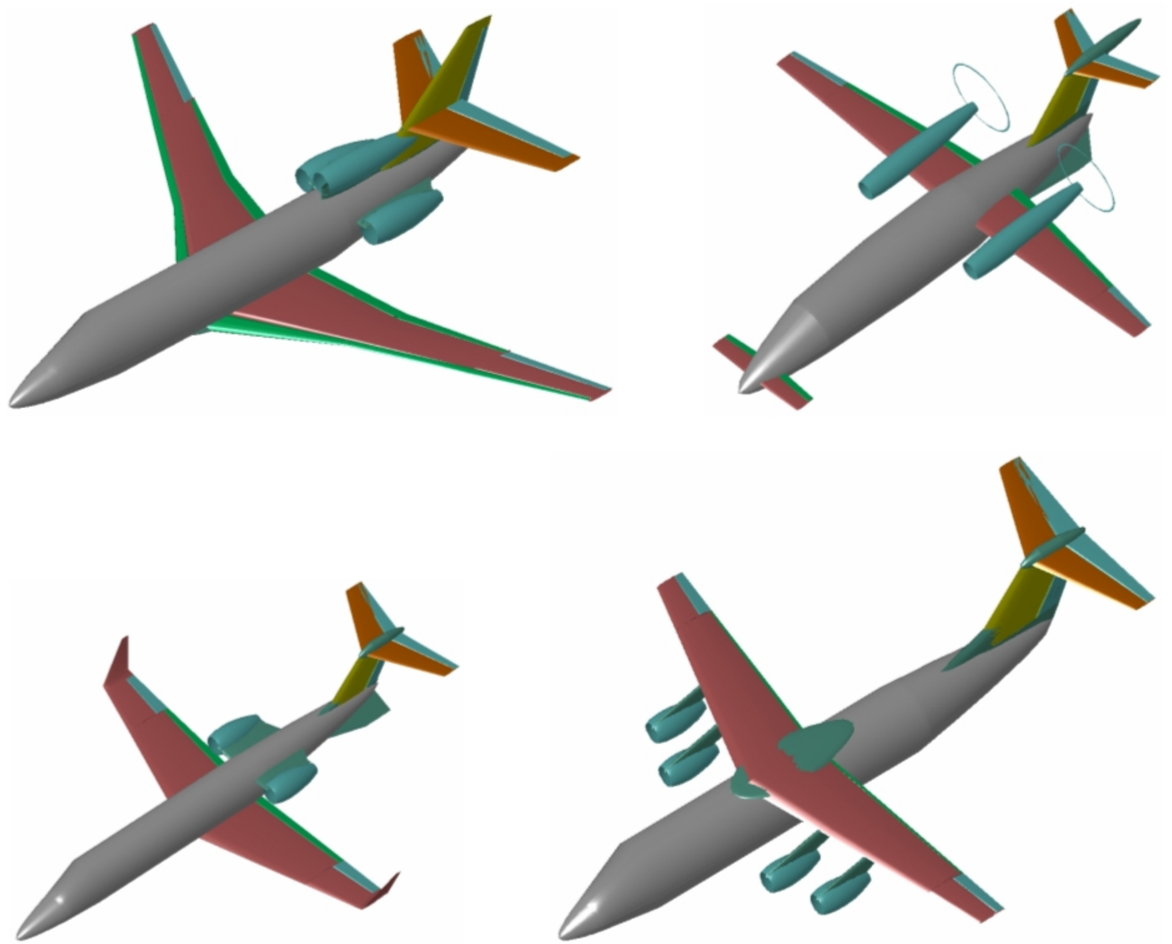
- **Architecture, design integration and analysis tool**
- **QCARD – Quick Conceptual Aircraft Research & Development**
  - ➢ User-interactive MATLAB-based conceptual design package
  - ➢ Tailor-made to predict, visualise and assist in optimising designs
  - ➢ 9 sub-spaces coupling
  - ➢ Permit trade-studies and risk assessment



- **CAD system integration**
  - ➢ MVO/MDO visualisation-analysis medium
  - ➢ Can interface with sizing decision support modules
- **Incorporate quantifiable uncertainty, robustness & modularity to solution synthesis process**

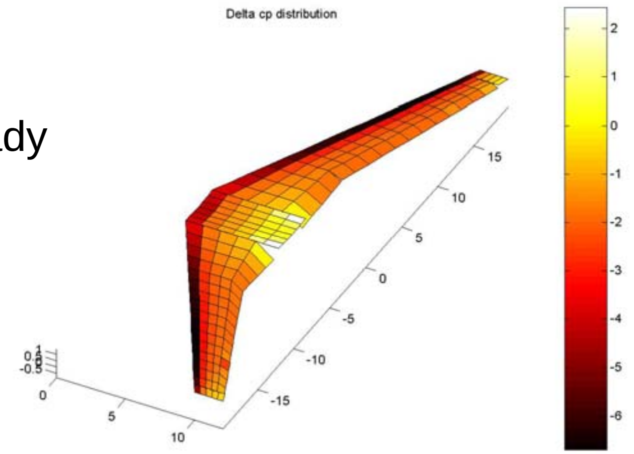


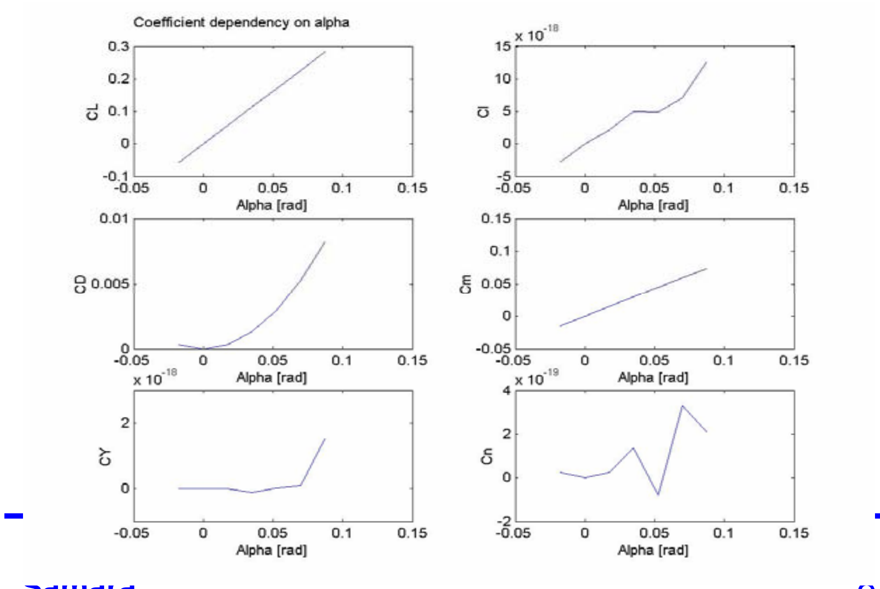
Examples of geometries in QCARD



Unsteady TORNADO - TORNADO

- Vortex lattice program developed by Tomas Melin at the division of aeronautics of the Royal Institute of Technology KTH, Stockholm
- Computation of lift, drag and moments coefficients in a steady case
- Widely used: Virginia Tech (US), Loughborough University (UK), Sao Paulo University (Brazil), Saint Cyr (France), Northwestern University of Polytechnology (China) ....





TORNADO CALCULATION RESULTS

JID:	q1	Downwash matrix condition:	11.9374
Reference area:	12.0714		
Reference chord:	1.5451		
Reference span:	9		

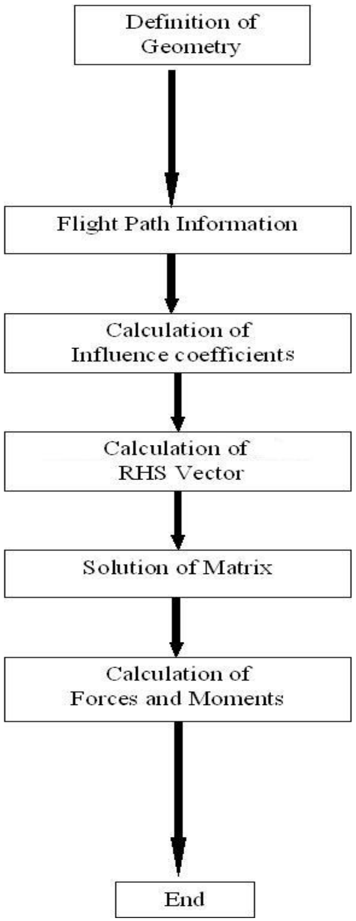
Net Wind Forces: (Nm)		Net Body Forces: (Nm)		Net Body Moments: (Nm)	
L:	332.4018	Z:	331.459	Pitch:	-726.1043
D:	7.1904	X:	-5.7027e-015	Yaw:	-4.9462e-014
S:	-5.7027e-015	Y:	-26.0303	Roll:	-1.8862e-013

CL	0.44957	CZ	0.4483	Cm	-0.63559
CD	0.009725	CX	-0.035206	Cn	-7.4331e-018
CY	-7.7128e-018	CC	-7.7128e-018	Cl	-2.8345e-017

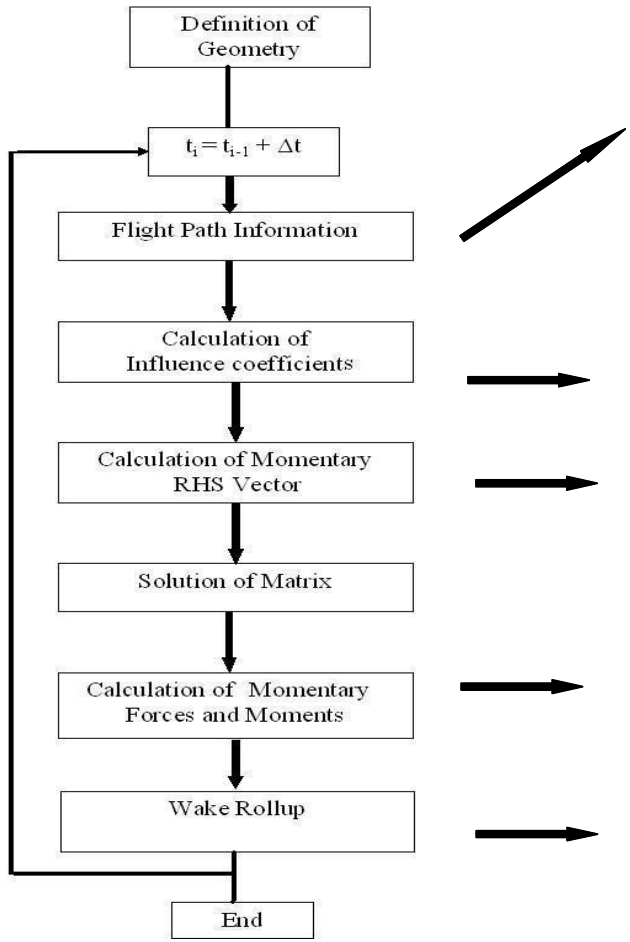
STATE:

alpha:	5.7296	P:	0	
beta:	0	Q:	0	Rudder setting [deg]:
Airspeed:	10	R:	0	
Density:	1.225			

Unsteady TORNADO – Resolution loops



Steady TORNADO



- Update speed, angle of attack …
- Move wake vortices according to the flow
- Create a new row of wake vortices from the trailing edges

- Self-influence of the wing
- Influence of the new wake vortices

- Wind
- Downwash
- Kelvin condition

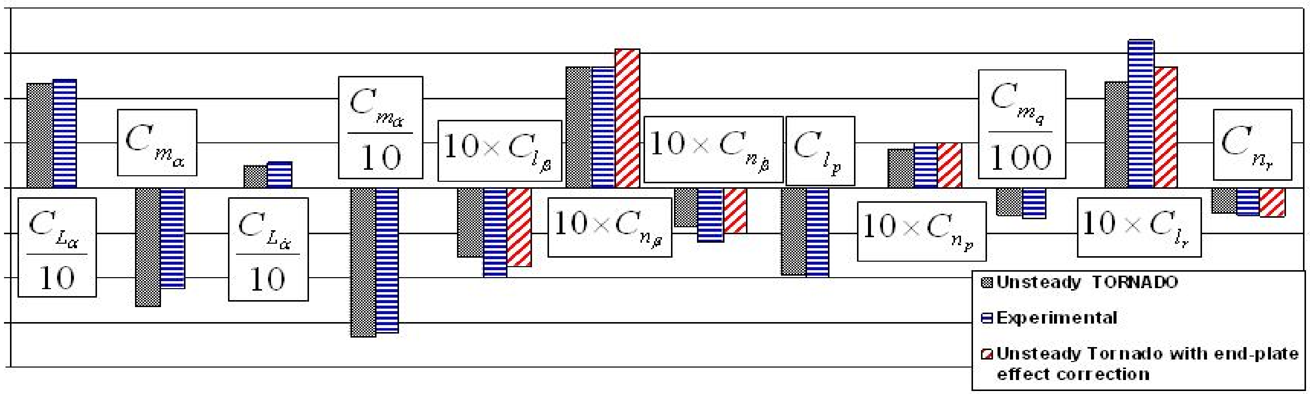
Steady and unsteady vector form of Kutta-Joukowsky theorem

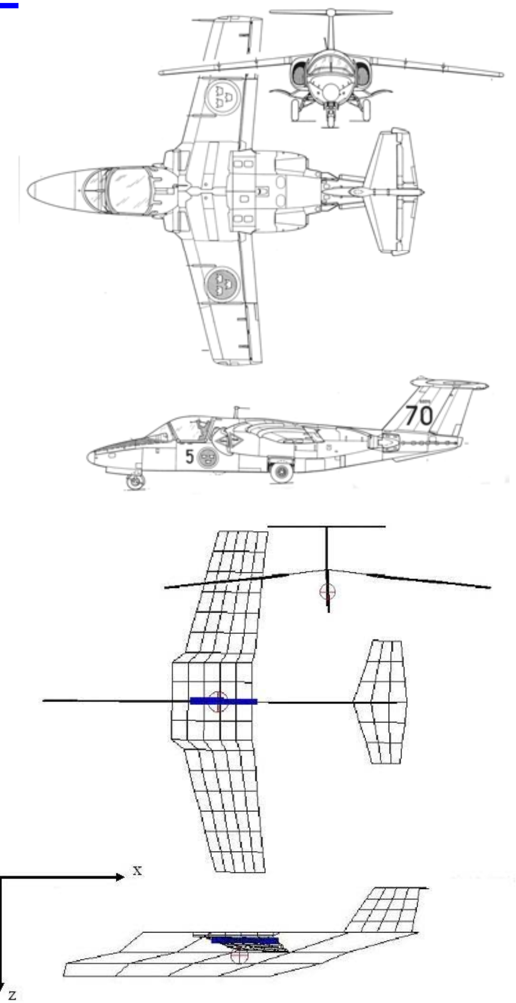
- Influence of wing on wake
- Self-influence of wake
- Optional

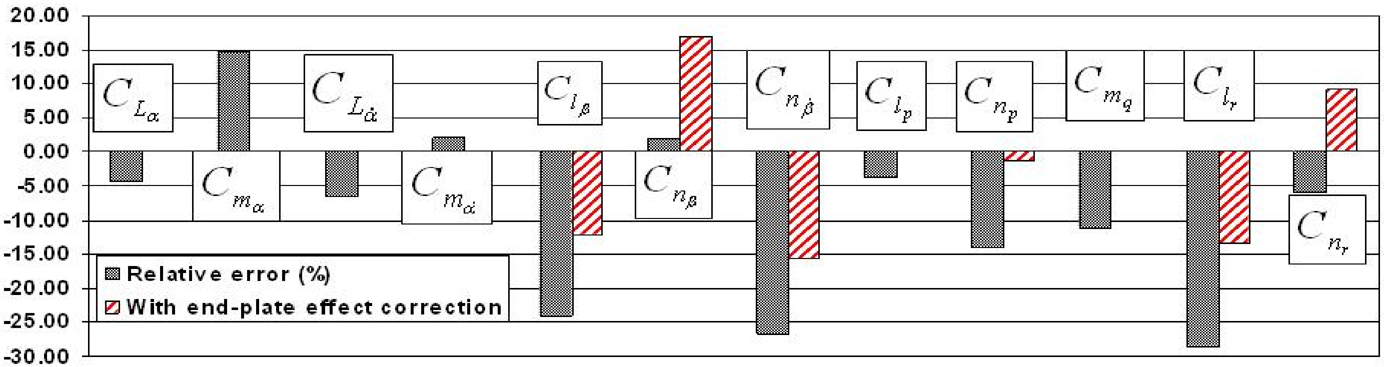
Unsteady TORNADO

Ref: Katz and Plotkin , Low-Speed Aerodynamics – From Wing Theory to Panel Methods

Unsteady TORNADO: SK105 benchmark







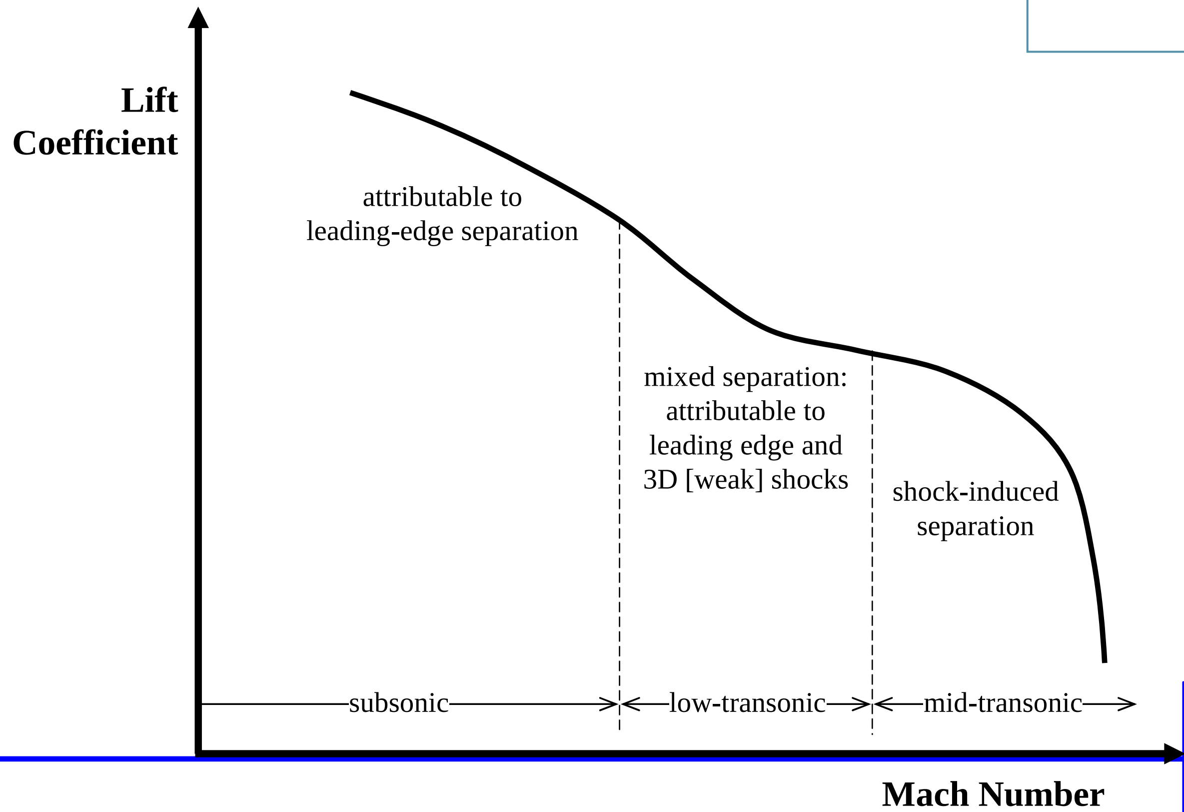
Buffet onset prediction - Buffet

Aerodynamic excitation due to separated flow

Vibrations in the flexible modes

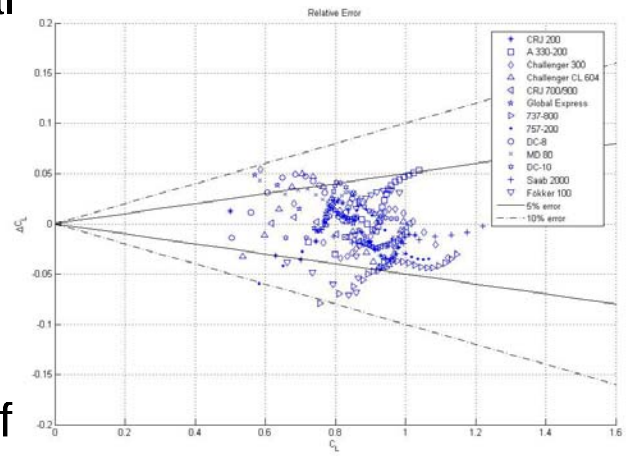
Affect strongly the aerodynamic performance

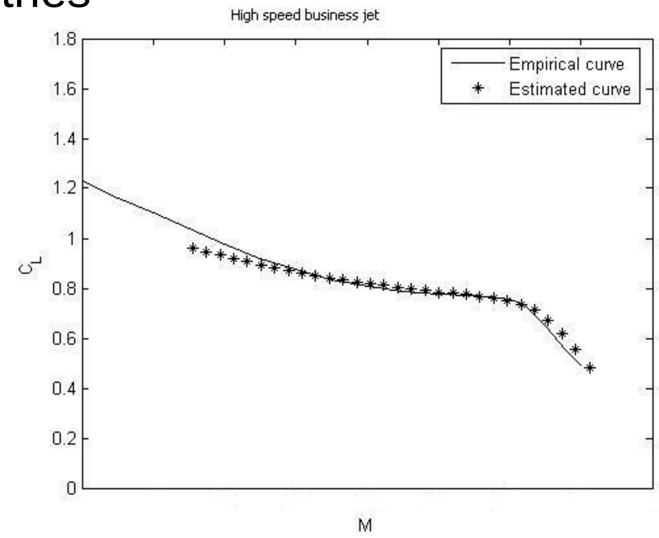
Severe steady or fatigue loads

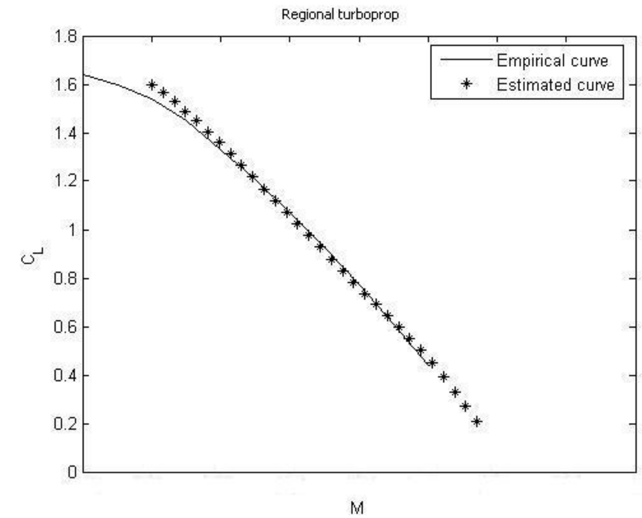


Buffet onset prediction: summary of results

- Combination of simple sweep theory and fractional change theory
- Six influencing parameters:
  - Reference wing planform: aspect ratio, taper ratio, quarter chord sweep
  - Tip airfoil section: camber, thickness to chord, chordwise position of maximum thickness to chord
- Accurately predicts buffet for a very wide variety of airplane geometries







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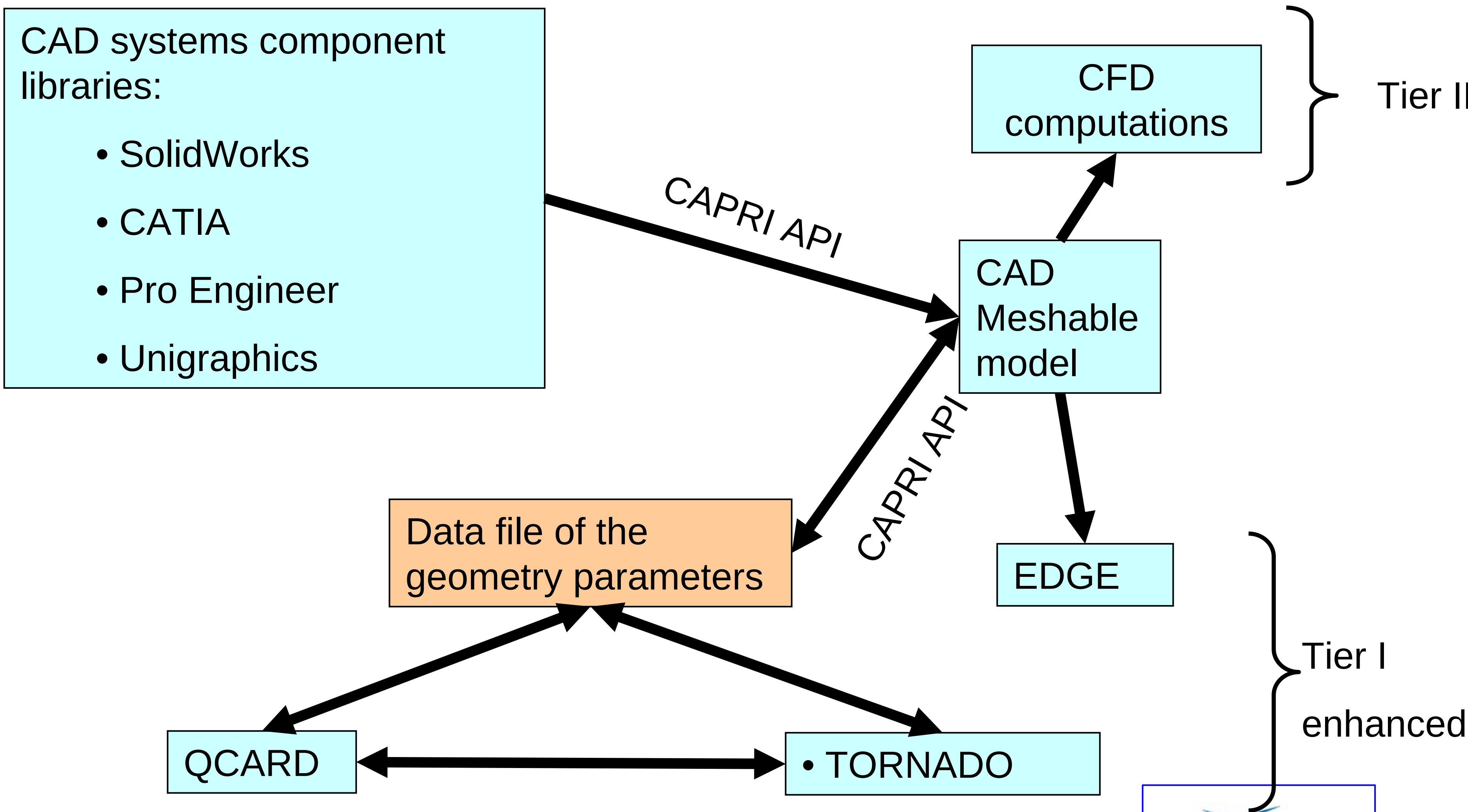
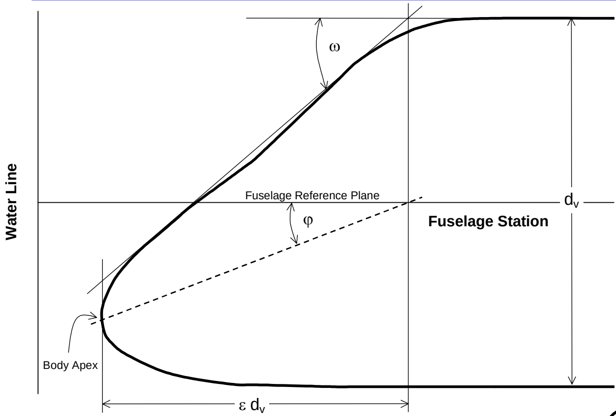
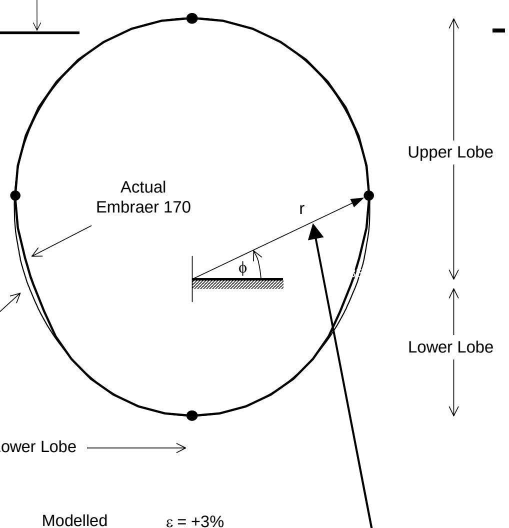
Master model concept



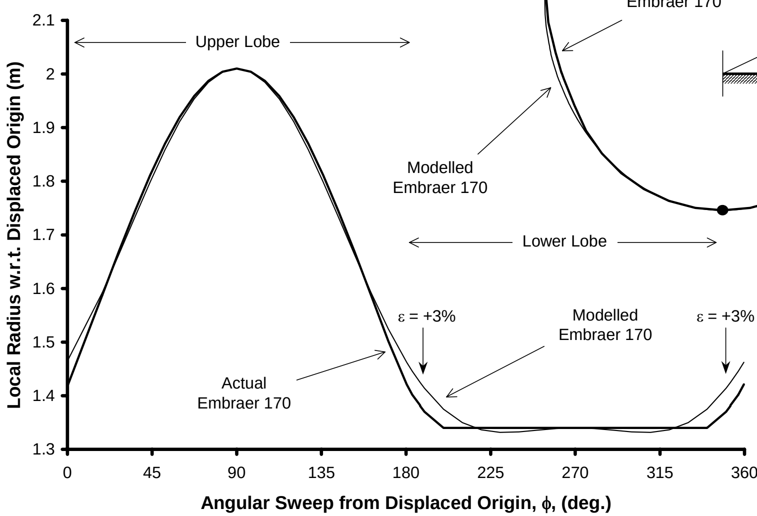
Parametric representation of airplanes in QCARD



- Each component of the airplane is defined by a set of parameters:
  - fuselage: diameters, nose downsweep …
  - wing: AR, taper ratio, planform …
  - others: nacelle, fairings, tails …



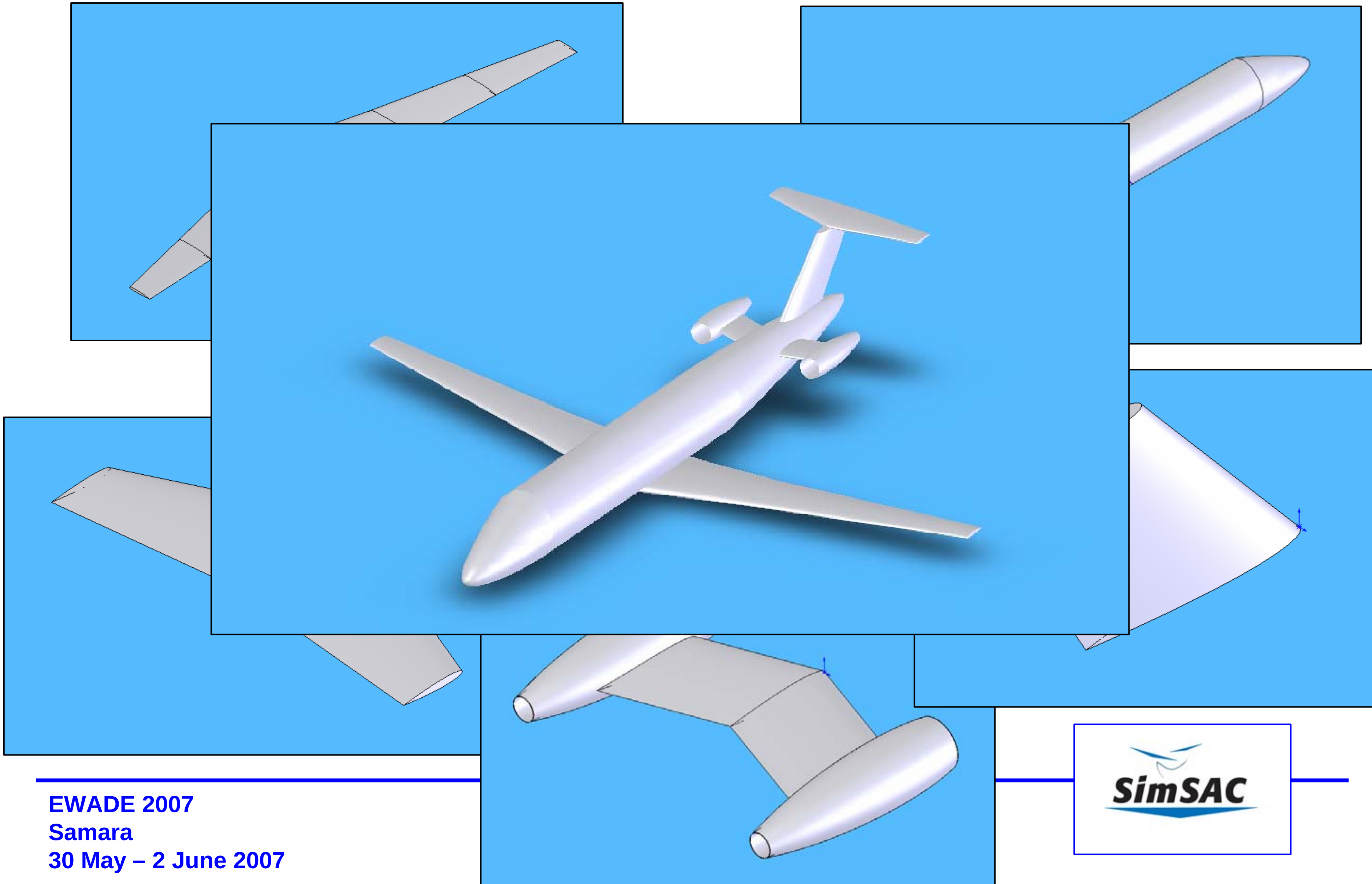
- The 3D representation of each component is based on semi-empirical parametric equations



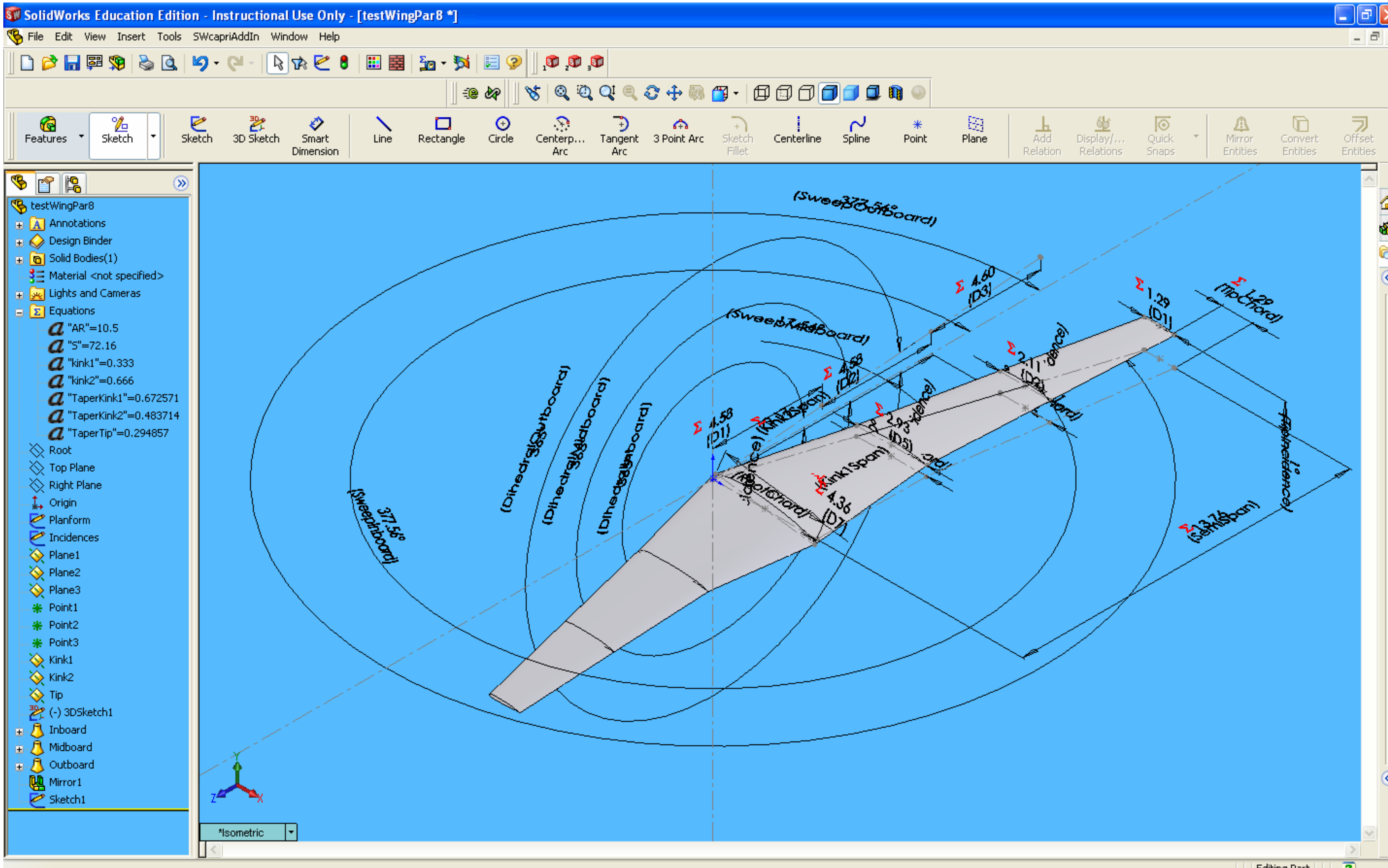
$$r(\phi) = 1.5698 - 0.10520\cos 2\phi + 0.33504\sin\phi$$

SimSAC

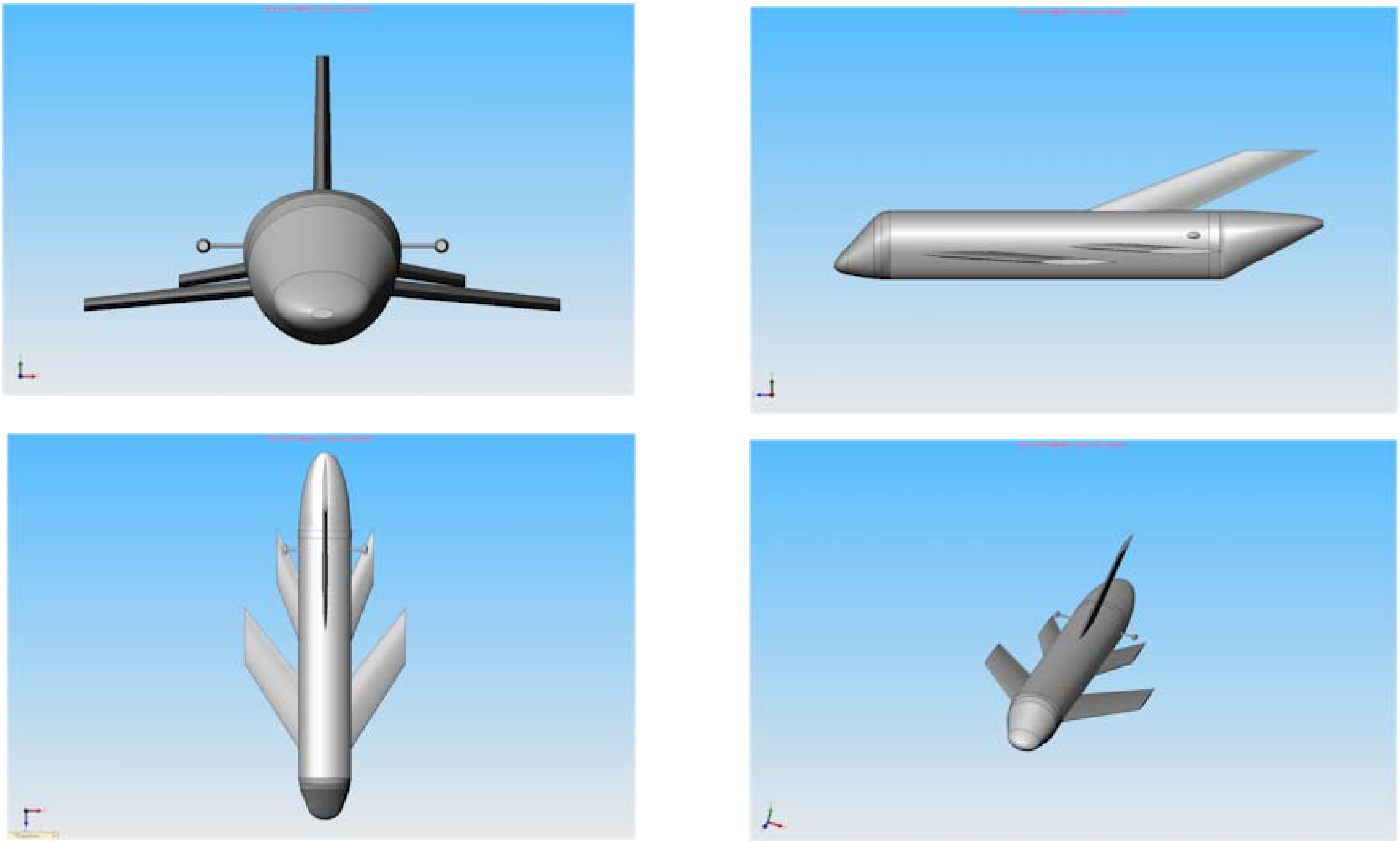
Library of components



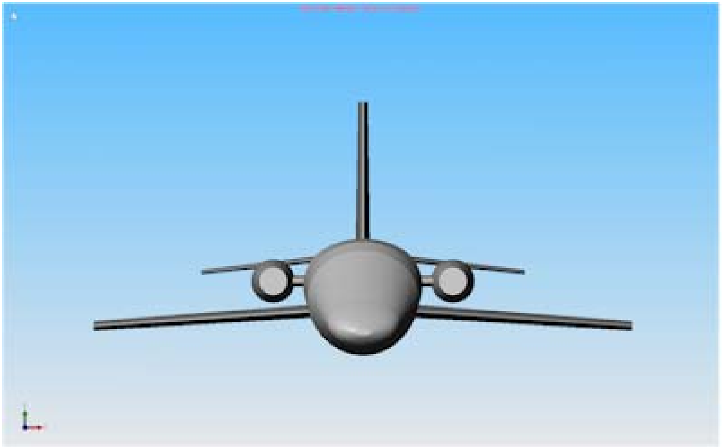
Parametrized wing in the CAD system

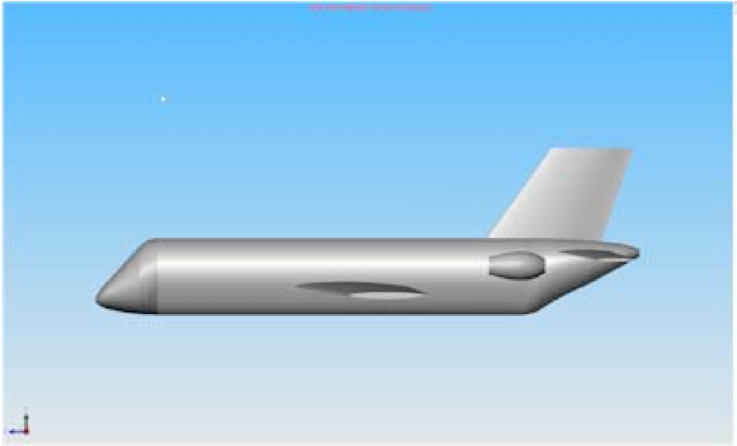


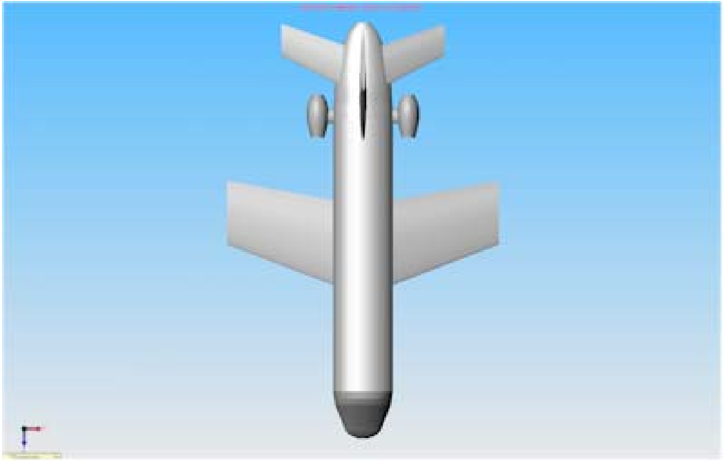
CAD exercise using SolidWorks

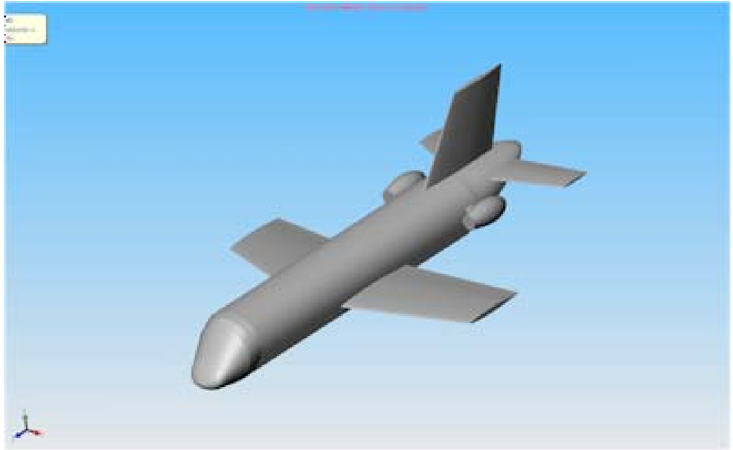


CAD exercise using SolidWorks

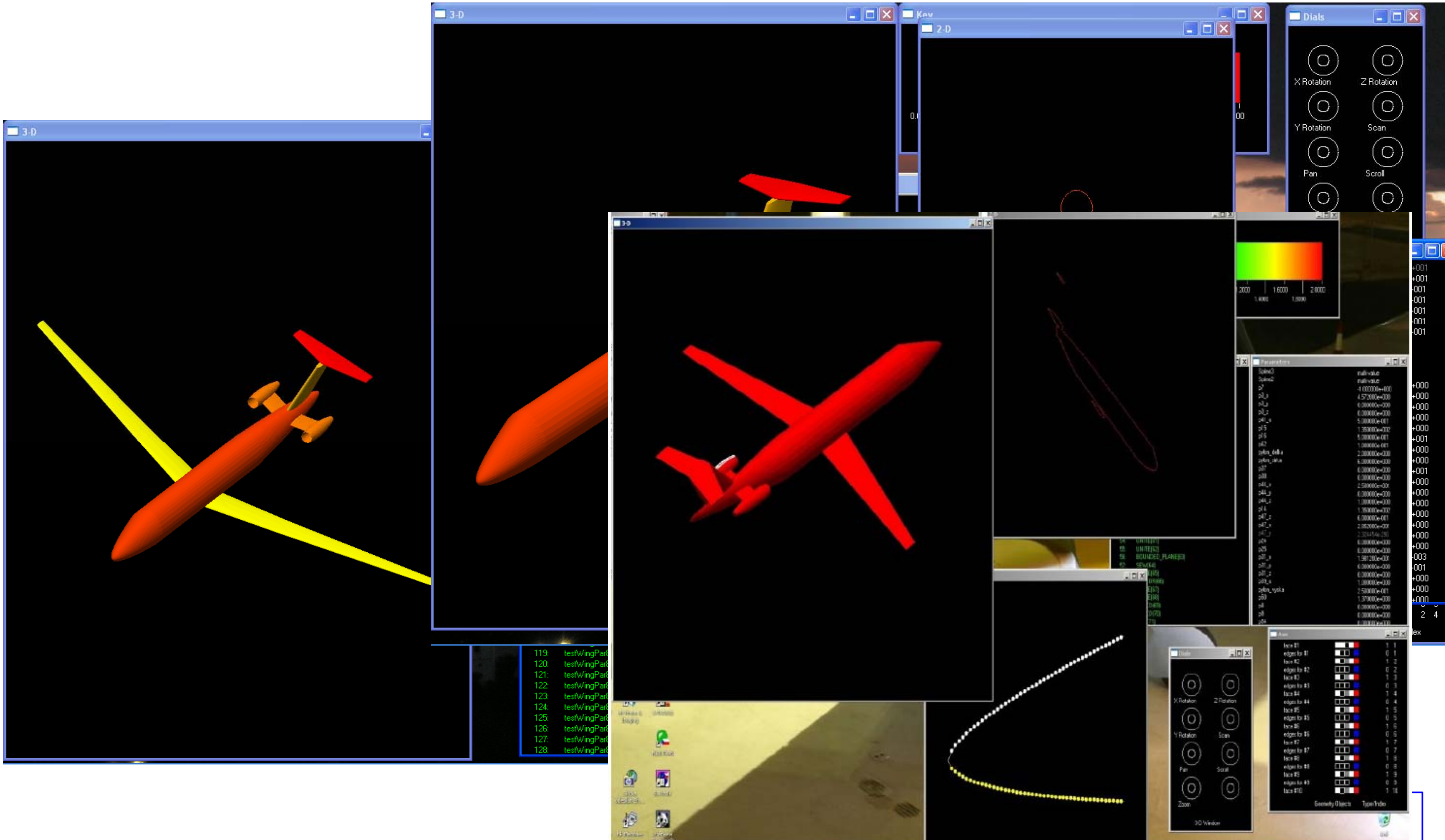




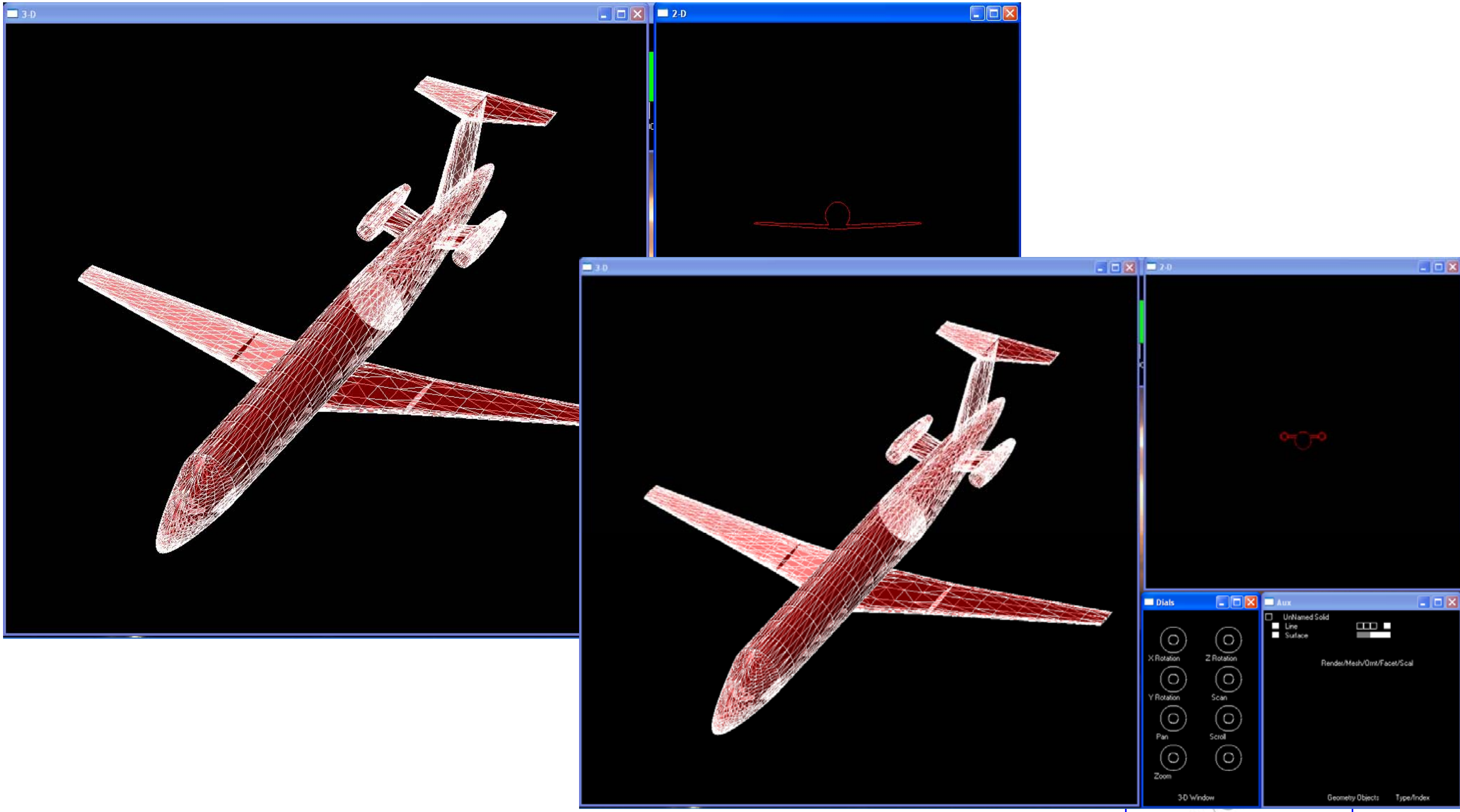




CAPRI API and « Master » function



CAPRI Tesselation and Boolean operation



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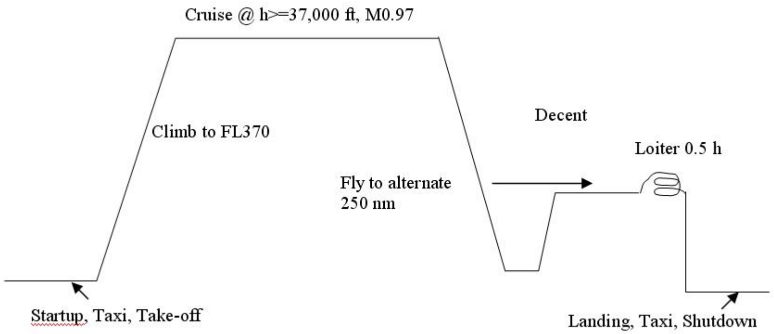
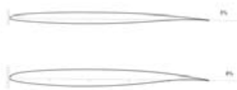
Design exercise: Transonic Cruiser

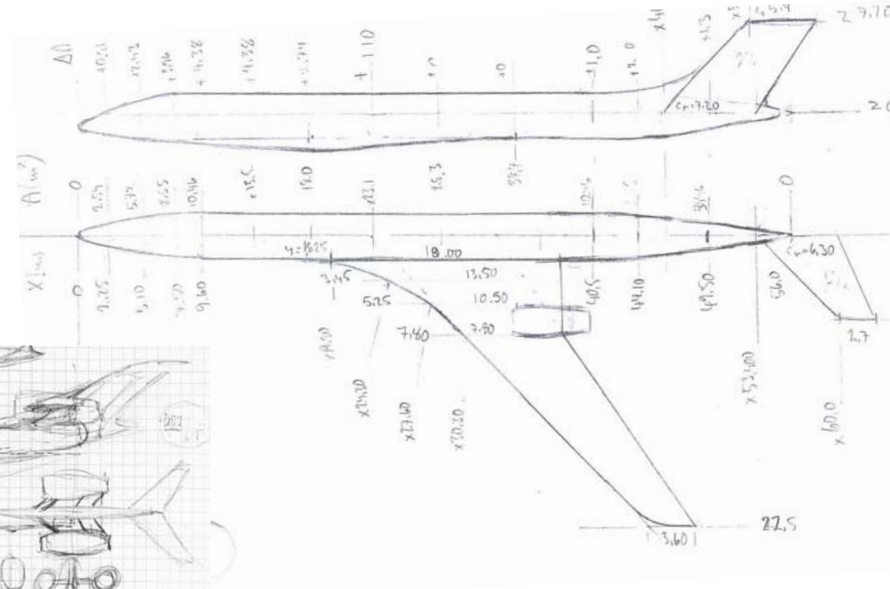
- **Design Specification for TCR (TransCRuiser)**[1]
- Payload: Nominal design for 200 PAX in Economy Class pitch 36”, 22,000 kg max payload. Baggage and freight in LD3-46W containers.
  Possibility to divide into Three Classes:
- 20 First Class pitch 44” width 19” (2+2 seats),
- 70 Business Class pitch 38” width 19” (3+2 seats), and
- 80 Economy Class pitch 36” width 19” (3+2 seats).
-
- Cabin and Crew: Six lavatories and two galleys with a total of 40 full size trolleys. Two pilots and six cabin attendants.
- Range: 5,500 nm, followed by 250 nm flight to alternate and 0.5 hour loiter at an altitude of 1,500 ft. Additional 5% of block fuel.
- Design cruise speed: MD = 0.97 at greater or equal to 37,000 ft.
- Climb: Direct climb to FL370 at max WTO.
- Take-off and Landing: TO distance 2,700 m at an altitude of 2,000 ft, ISA +15 and max WTO. Landing distance 2,000 m at an altitude of 2,000 ft, ISA and max WL with max payload and normal reserves.
-
- Powerplants: Two Turbofans.
- Pressurization: According to EASA.
- Noise requirement: According to ICAO.
- Certification Base: JAR25.

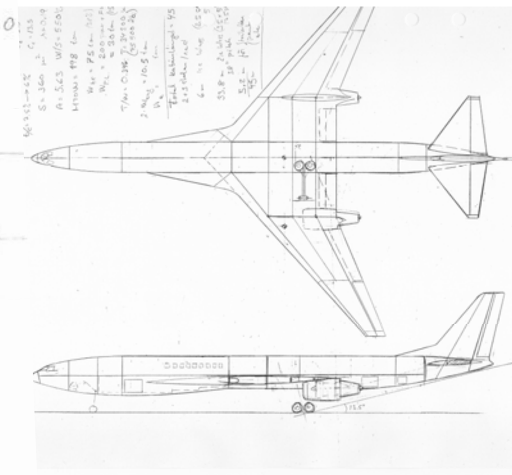


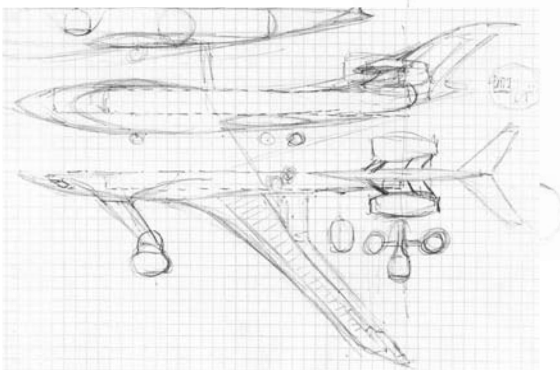
[1] Based on AEA Long Range Requirements.

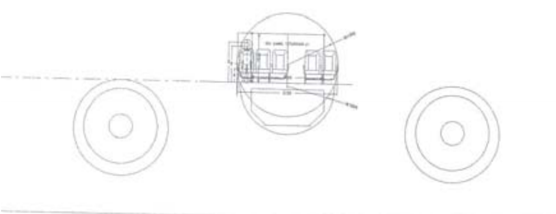
Design exercise: Transonic Cruiser

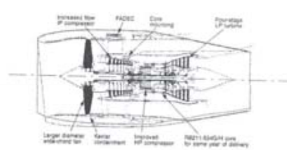


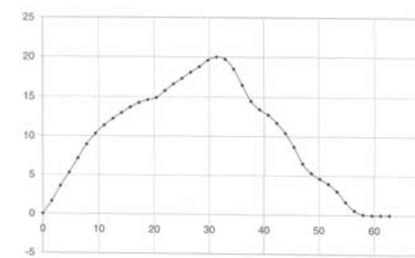




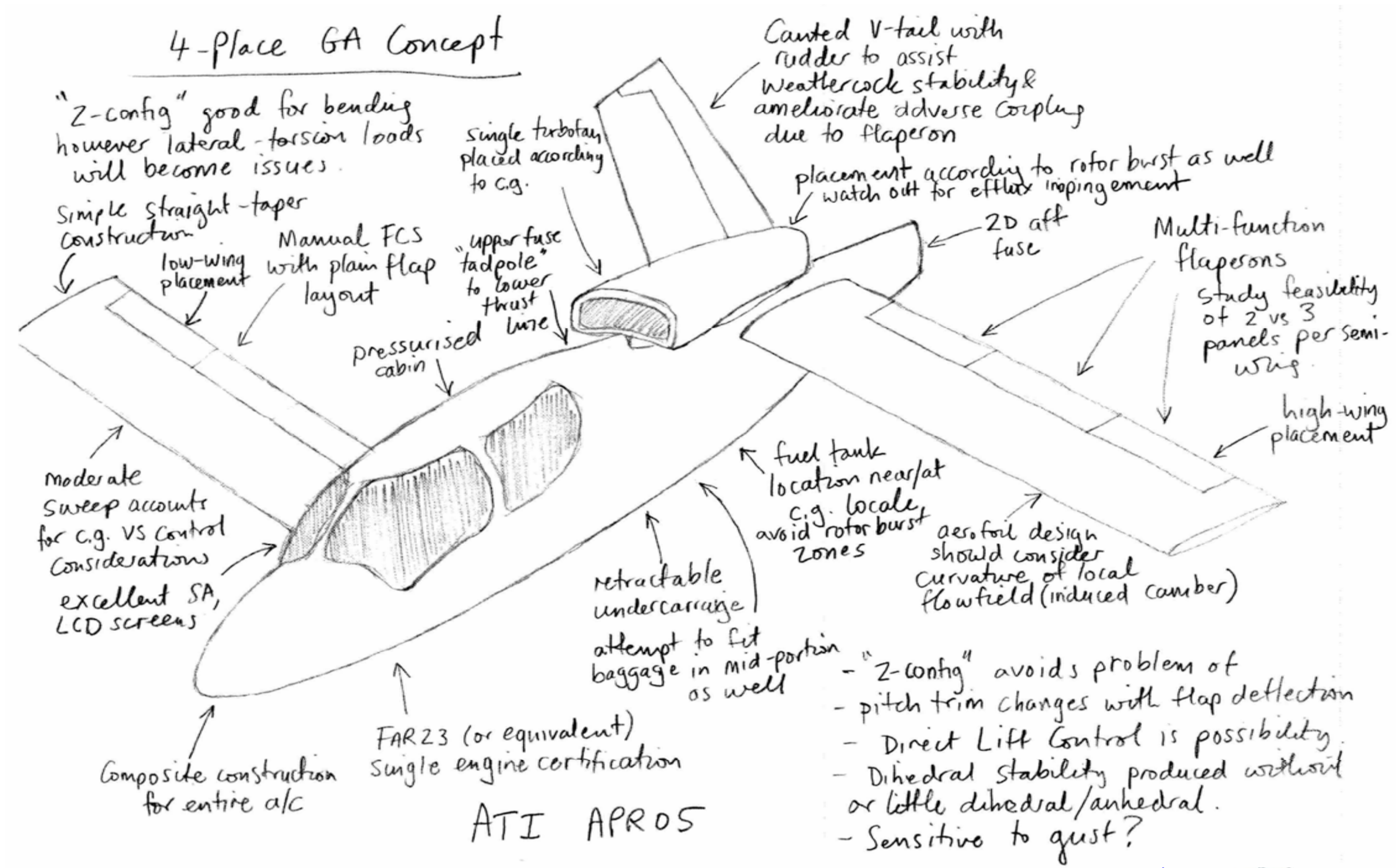




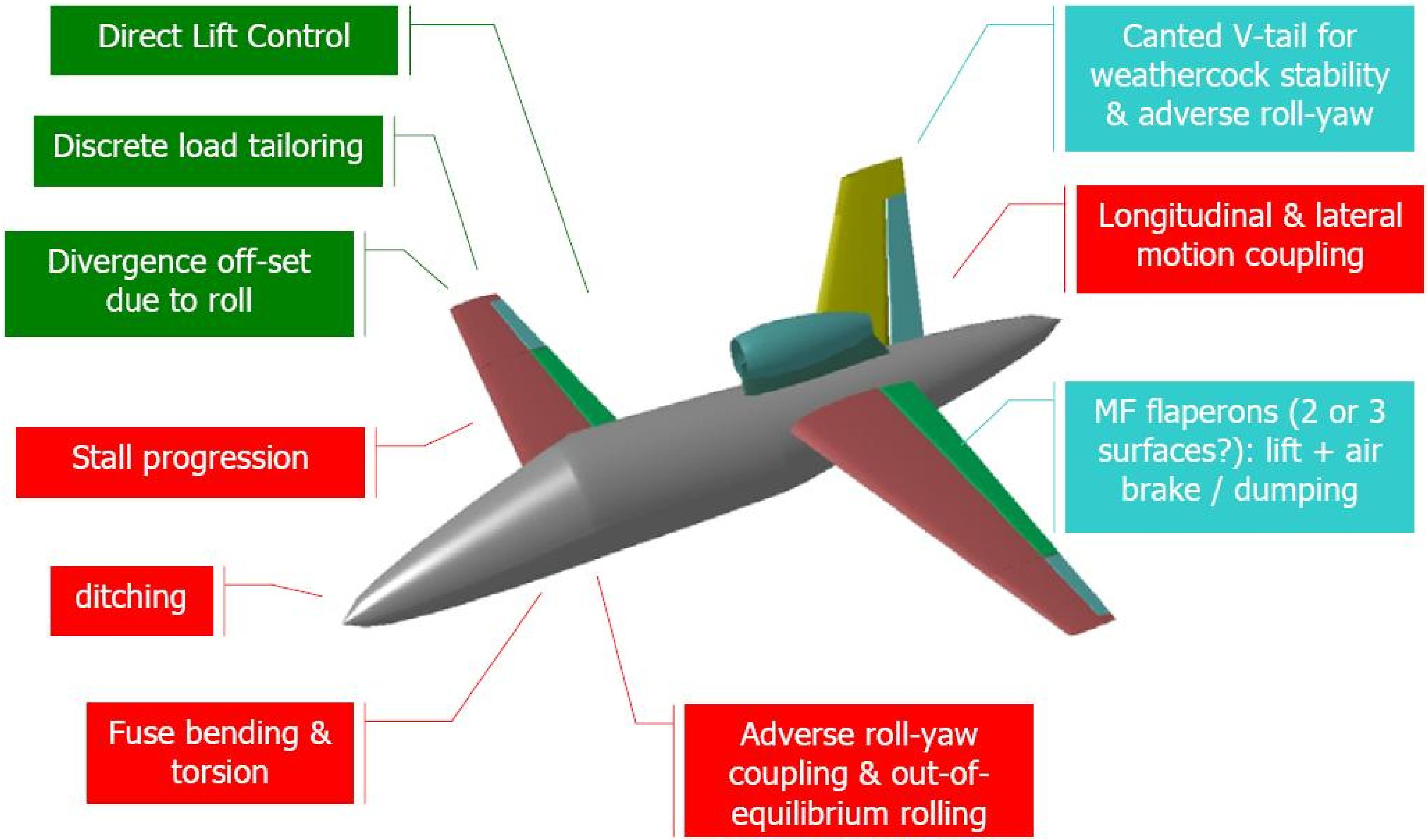




Design exercise: Z configuration



Design exercise: Z configuration



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